Fact Sheet

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WCWC Walkerton Clean Water Centre
An agency of the Government of Ontario
CWAE Centre de Walkerton pour l'assainissement de l'eau
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Small Drinking Water Systems and Blue-Green Algae Toxins

Key Words: Small Systems, Cyanotoxins, Microcystins, Microcystin-LR, Blue-Green Algae

Cyanobacteria (Blue-Green Algae) and Cyanotoxins

Cyanobacteria, commonly called blue-green algae, are microscopic bacteria that have some characteristics similar to algae. They naturally occur in surface waters and can form widespread discolouration in the water, called a bloom. Blooms can occur when conditions, such as warm temperature, high nutrients and light conditions are favourable for growth. Some species can produce toxins, known as cyanotoxins, which can have harmful effects on the nervous system, liver and/or irritate the skin. One of the most common cyanotoxin is microcystin, which can be produced by several species of blue-green algae. Specifically, microcystin-LR (MC-LR) is the most studied cyanotoxin and commonly found in freshwaters (Rinehart *et al.* 1994, Carmichael 2000). To ensure safe drinking water, the Ontario Drinking Water Quality Standards established a maximum acceptable concentration of the most common toxin, MC-LR of 1.5 µg/L (MOECC O.Reg. 169/03).

Drinking Water Treatment Challenges

Typically, blue-green algae produce and store cyanotoxins internally, but as they age or if the cells become damaged, cyanotoxins can be released. Cyanotoxins can exist in two forms (Fig. 1-1):

- **Cell-bound**: blue-green algae cells are healthy and cyanotoxins are stored internally.
- **Released**: cyanotoxins are released as blue-green algae cells age or become damaged and deteriorate.

It can be challenging to select a drinking water treatment process that is appropriate to remove or destroy cyanotoxins because some treatment processes may rupture cells, which release toxins (Fig. 1-2). Additionally, different treatment processes may only effectively remove/degrade either cell-bound or released toxins (Fig. 1-3).

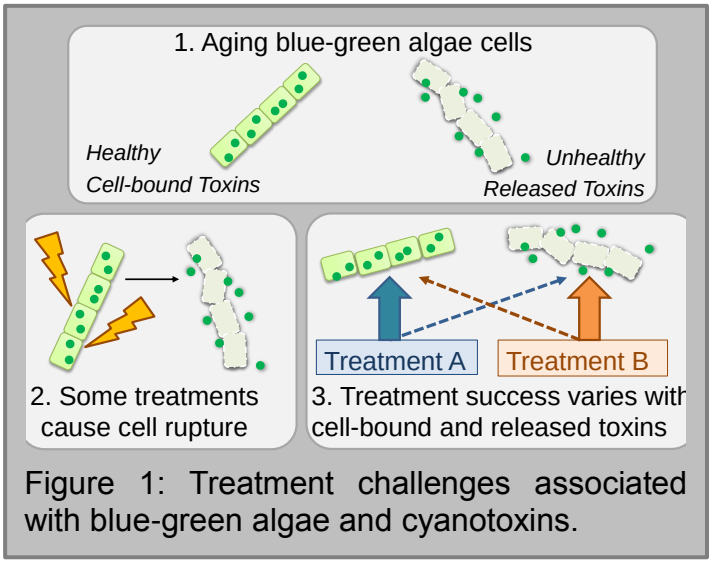

Figure 1: Treatment challenges associated with blue-green algae and cyanotoxins.

In early stages of a blue-green algae bloom, treatment plants should aim to remove intact cells using a method that will decrease cell damage and prevent the release of toxins. In later stages of a bloom, cells will naturally degrade and toxins will be released, which poses an additional challenge for water treatment plants.

What do we know about cyanotoxin impacts on small drinking water systems?

In Ontario, there are approximately 18,000 small drinking water systems that are governed by the Ministry of Health and Long-Term Care (MOHLTC 2009). However, few studies have investigated the effect of small drinking water system technologies on the removal of blue-green algae or cyanotoxins.

Ion exchange resin and granular activated carbon (GAC) cartridge filters have been shown to remove 60% of filamentous blue-green algae cells, 10% of single cells and 40-57% of MC-LR if the filters are pre-rinsed, flushed and filtered repeatedly (Lawton *et al.* 1998) (Fig. 2). Another study found that carbon-based cartridge filters remove 99% of MC-LR, whereas fiber-wound and pleated paper cartridge filters only remove 6% and 5% of MC-LR, respectively (Neumann and Weckesser 1998) (Fig. 2). Reverse osmosis (RO) has been shown to remove 97% to 99% of MC-LR however, operators should be cautious that toxins could accumulate in the RO waste (Neumann, U. and Weckesser, W. 1998). Ultraviolet (UV) treatment can only degrade 50% of MC-LR after 10 minutes of UV irradiation at 147 µW/cm^2; however, the dosage may be impractically high for basic disinfection needs (Tsuji *et al.* 1997) (Fig. 2).

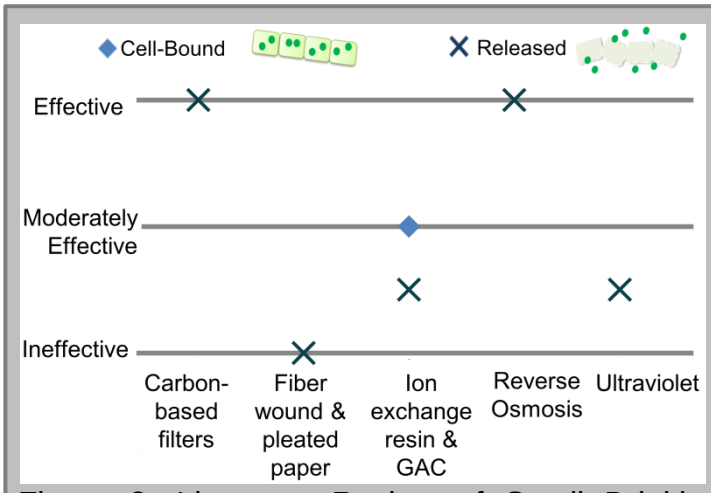

Figure 2: Literature Review of Small Drinking Water System Technologies to Treat Cell-bound and Released Toxins.

Overall, small drinking water system technologies are not well studied for removing cyanotoxins, such as MC-LR.

Objective

The Walkerton Clean Water Centre completed a pilot testing project to investigate small drinking water treatment technologies on the removal of microcystins and blue-green algae using a natural bloom. Technologies included pleated cartridge filters (20 µm, 5 µm and 1 µm) in series as pre-treatment followed by carbon block filtration, ceramic microfiltration, ultrafiltration, nanofiltration, reverse osmosis and ion exchange, in parallel (Fig. 3). Roughing filtration, followed by slow sand filtration was also pilot tested (Fig. 3).

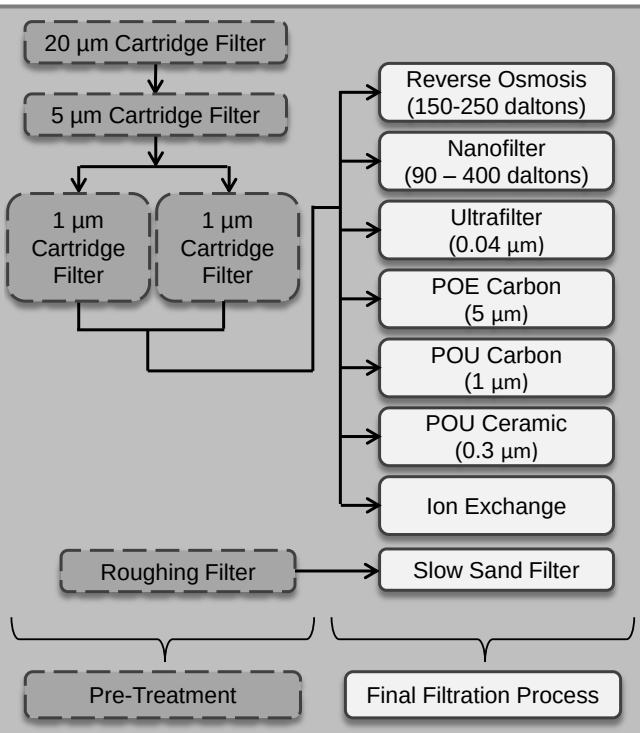

Figure 3: Pilot Testing Processes. The reverse osmosis (RO), point of entry (POE) and point of use (POU) carbon block filters and ion exchange were pilot tested side-by-side. The nanofilter (NF), ultrafilter (UF), ceramic microfilter and slow sand filter were pilot tested side-by-side in a separate experiment. All processes ran for six hours, except UF ran for four hours.

What did we learn from the WCWC pilot testing project?

This study used a mild-moderate blue-green algae bloom as the raw water source. In the raw water, blue-green algae cells ranged from 6,660 to 22,300 cells/mL and MC-LR ranged from 0.19 to 0.29 µg/L. The pre-treatment combined cartridge filters (20 µm, 5 µm and 1 µm) removed on average 87% of blue-green algae cells, with the 1 µm cartridge filter capturing the majority of cells. The pre-treatment combined cartridge filters (20 µm, 5 µm and 1 µm) removed on average 91% of MC-LR, with the 20 µm cartridge filter capturing the majority of toxins. The toxins were likely cell-bound and the 20 µm cartridge filter captured the toxin-containing cells.

Including pre-treatment, reverse osmosis, nanofiltration, ultrafiltration, ceramic microfiltration and POE carbon block filtration removed ≥ 99.9% of blue-green algae cells (Table 1). Reverse osmosis, nanofiltration, carbon block filtration and slow sand filtration removed ≥ 95% of the cyanotoxins, MC-LR (Table 1).

Limitations and Next Steps

This study confirms the importance of implementing a multiple barrier treatment process to capture cell-bound and released cyanotoxins. This study focusses on water treatment technologies; however source water protection and watershed management are critical aspects to mitigate blue-green algae.

All treatment trains (Figure 3) removed a high percentage of blue-green algae cells and MC-LR using the natural blue-green algae bloom water source. However, the tested water had a mild-moderate level of cell density and MC-LR concentration and this study only involved a six hour run time. Further studies will need to investigate the performance of these systems in a denser blue-green algae bloom for a longer run time.

Blue-green algae vary with cell size and shape. Therefore, parallel studies may vary if the blue-green algae communities differ.

Additionally, this study did not assess the adsorption and desorption rate of filtration systems or operational challenges (e.g. cleaning or replacement requirements) of each system. Further studies will need to investigate this scope of the project.

Table 1. Removal of blue-green algae cells and MC-LR by the processes indicated in Figure 3.

Treatment Process	99.9% or higher of blue-green algae cells removed	95% or higher of MC-LR removed
Pre-Treatment + Reverse Osmosis	✓	✓
Pre-Treatment + Nanofilter	✓	✓
Pre-Treatment + Ultrafilter	✓	(81%)
Pre-Treatment + POE Carbon Block Filter	✓	✓
Pre-Treatment + POU Carbon Block Filter	(97%)	✓
Pre-Treatment + Ceramic Microfilter	✓	(86%)
Pre-Treatment + Ion Exchange	(82%)	(90%)
Pre-Treatment + Slow Sand Filter	(97%)	✓

Note. Run time was 6 hours, except otherwise indicated. The raw water contained 0.19 to 0.29 µg/L of MC-LR and 6,660 to 22,300 blue-green algae cells/mL.

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Related Training Courses

WCWC may offer courses related to this topic. Please browse our course descriptions to learn more about related training: www.wcwc.ca/registration

For More Information

For further information about this pilot testing project, contact WCWC.
For further information and resources on drinking water research and water operator training programs, please visit our website: www.wcwc.ca

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